Ethanol from Cane Molasses

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PRAJ INDUSTRIES LTD.

PUNE, INDIA

DOE+BBI Hawaii Ethanol Workshop, November 14, 2002
Honolulu, Hawaii.

PRAJ - Background

- Over 250 customers around the world.
- Over 60 distilleries attached to sugar mills.
- Fermentation process using cane molasses , syrup of sugarcane juice or mixture, grains, cassava etc.
- Has mapped molasses characteristics by analyzing more than 1500 cane molasses samples across the world.

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PRAJ - Infrastructure & Strengths

- Established knowledge based company with expertise in Fermentation,Distillation and in value added options for vinasse treatment & disposal.
- *MATRIX* - Technology Development Center with Analytical Laboratory & Pilot Plant Facilities.
- Central Technology and Engineering Facility with over 200 Experts for Design, Engineering, Project Management, Manufacture ,Installation & Commissioning of Alcohol Plants.
- Manufacturing facility for stainless steel, copper titanium etc.with ISO 9002 and ASME-U & H.

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PRAJ - Customers

- Seagram India.
- Allied Domeque.
- PT Molindo Raya, Indonesia.
- La Tondena, Philippines.
- Destilerias Unidas, Peru.
- Sucromiles, Colombia
- Destileria Brugal, Dominican Republic.
- West Indies Rum, Barbados.
- Thai Alcohol Company.
- McDowell & Company.
- Shaw Wallace.

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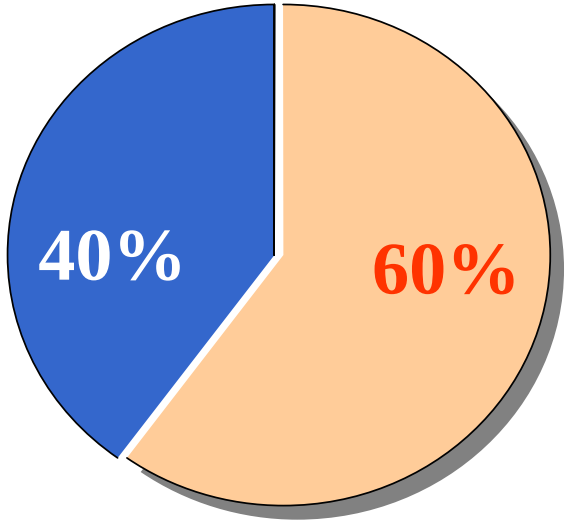
Utilization of Molasses

…..An overview



Ethanol Production from Cane Molasses is Over 20 billions Litres per Annum.

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Availability of Molasses

- Tropical Climatic Conditions Influence Many Technical Aspects of Molasses to Ethanol Fermentation.
- Majority of Molasses to Ethanol Plants are Concentrated in Tropical & Sub-tropical Regions.
- India has more than 200 distilleries using cane molasses. Other major producers od ethanol from cane molasses are Thailand, Indonesia, Philippines, Brazil, Guatemala, Mexico etc.

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Factors Affecting Composition of Molasses

- Variety of cane
- Composition of soil
- Climatic conditions
- Harvesting practices
- Sugar manufacturing process
- Handling and storage

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Typical Composition of Molasses

• Total Solids	: 75 to 88 % Wt.
• Total reducing sugars	: 44 to 60 % Wt.
• Unfermentable Sugars	: 4 to 5 % Wt.
• Fermentable Sugars	: 40 to 55 % Wt.
•Total Inorganics	: 8 to 12 % Wt.
• Settlable dry sludge	: < 3.5% Wt.
• Specific Gravity	: 1.38 to 1.52
• Titrable volatile acidity	: 3000-20,000 ppm
• pH at 40 deg. Diluion	: 4.5 to 5.6
• Caramel(OD)	: 0.2 to 0.6

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Mapping Characteristics of Cane Molasses

	Analytical Parameter	SOUTH AMERICA	AFRICA	SOUTH EAST ASIA	CARRABIAN
A	**Chemical Analysis**				
1	Brix (Degree Brix) At ambient temp.	87- 93	83 - 91	78 - 85	84 - 93
2	Total Solids (% w/w)	81 - 86	82 - 85	78 - 85	74 - 79
3	Total sugars as reducing matter (% w/w)	49 - 54	48 - 55	50 - 60	52 - 56
4	Un-fermentable sugars as reducing matter (% w/w)	2.5 - 5.2	2.3-5.4	3.7-4.9	3.5 - 4.5
5	Fermentable sugars (% w/w)	43.5 - 50	43- 49.5	45 - 60	47.5 -52
6	F:N Ratio	1.0 - 1.6	1.0 - 1.5	1.2 - 2.8	1.7- 2.8
7	Total inorganic matter (% w/w)	7.8 - 14	6.5 - 8.5	4 - 5	9 - 12
8	Calcium as CaO (% w/w)	1.3 - 3.9	2 - 3	1.9 - 2.5	1.8 - 2.6
9	Total Settlable dry sludge at pH 4.5 and 40 Brix dilution (% w/w of raw molasses)	0.7- 4.5	0.5 - 3.0	0.5 -1.0	1 - 1.5
10	Total settlable sludge at pH 4.5 – 4 Hr settling (by Vol. %)	15 - 26	5 - 20	1- 6	0 - 12
11	Specific Gravity(at ambient temperature)	1.46 - 1.50	1.43 - 1.51	1.40 - 1.45	1.44 - 1.49
12	Titrable volatile acidity in terms of acetic acid and acetate salts (PPM)	5500 - 22500 Average 12000	6500-12500	5500-11500	4000 - 5500
13	PH at 40 Brix dilution	5-5.5	4.8-5.5	4.6-5.3	4.8 - 5.4
14	Dry suspended particles (> 100 µ) (% w/w)	ND	ND	ND	ND
15	Colour in terms of optical density (OD) at 375 nm with 0.1 % w/v dilution.	0.2- 0.32	0.3 - 0.49	0.2 - 0.55	0.35 - 0.4
B.	**Microbiological Analysis**				
1	Total Viable count cfu/gm	100 – 20000	100-600	3000-40000	1000-4000
C Instrumental (GC) analysis of Individual Free Volatile fatty acids (By-products of bacterial metabolism).					
1	Acetic Acid (PPM)	4000-22000	2000-3000	5000-7000	4000-5000
2	Propionic Acid (PPM)	30-250	30-50	80-90	35-40
3	Isobutyric acid (PPM)	300-600	10-20	40-60	20-40
4	Butyric acid (PPM)	100-220	60-70	40-60	300-355
5	Isovaleric acid (PPM)	10-50	200-230	100-114	400-430
6	Valeric acid (PPM)	10-40	5-10	5-10	5-10
7	Total Acids by GC (PPM)	4450- 23200	2300-3400	5300- 7350	4700- 5900

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General observations about Cane Molasses

- South American molasses is generally high in fermentable sugars, high in calcium, inorganic ash and volatile acidity.
- Caribbean molasses is normal in calcium and volatile acidity & high in fermentable sugars.
- Molasses in Central America has moderate fermentables, medium VA & high in caramel
- African molasses is high in fermentable sugar low calcium & sludge content and normal VA.
- South East Asian molasses is high in fermentable sugars, high volatile acidity & higher in caramel.
- Molasses in northern & southern India has low fermentable sugars, higher VA & caramel.

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Fermentation of Molasses to Ethanol

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What is Fermentation ?

Fermentation of Sugar.

Fermentable sugar gets converted in to ethanol with yeast as catalyst.

Reaction:

Di-saccharide ----------> Mono-saccharide

Mono-saccharide ----------> Ethanol + CO_2

Yeast

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Factors in Molasses Influencing Fermentation

- **Fermentable Sugars**

Yeast uses fermentable sugar for ethanol production.

- **Inorganic Salts**

Salts inhibits yeast activity due to Osmotic pressure.

- **Volatile Acidity**

Volatile acids reduce yeast growth and ethanol formation.

- **Hygienic Conditions**

Hygienic condition controls contamination.

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Composition of Molasses & Effects on Fermentation Kinetics

- F:N ratio < 0.9 retards fermentation rate by average 15 - 20 %
- Ash content above 10 % can retard the rate of fermentation by 5 - 10 %.
- Extent of caramelization : (Measured as color in OD units at 375 nm of 0.1 % molasses solution)> 0.40 OD retards fermentation rate by 20-25%.Reaction ceases beyond 0.65.
- Volatile acids in mash > 2500 ppm reduce the rate of fermentation and yeast growth.
  Volatile acids in mash > 5000 ppm reduce fermentation rate by 30 - 40 %.
  Volatile acids in mash > 7000 ppm can kill the yeast reducing viability up to 40-50 %.

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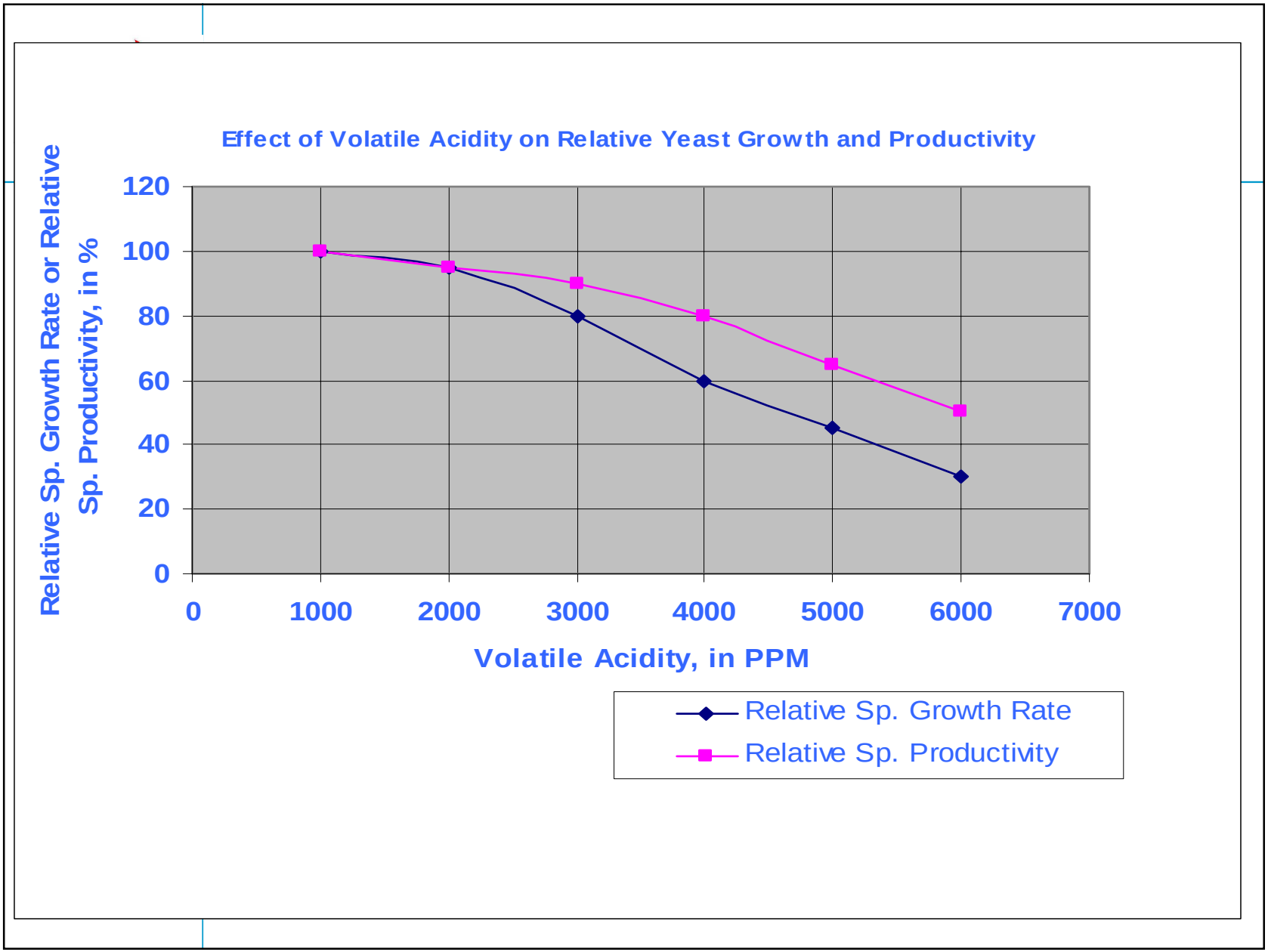
Effect of Volatile Acidity on Relative Yeast Growth and Productivity
Relative Sp. Growth Rate or Relative Sp. Productivity, in %
120
100
80
60
40
20
0
0
1000
2000
3000
4000
5000
6000
7000
Volatile Acidity, in PPM
Relative Sp. Growth Rate
Relative Sp. Productivity

Parameters For Fermentation

- Alcohol concentration in Mash.
- Sugar & Yeast Concentration in Mash.
- Temperature & pH of Mash.
- Volatile acidity in Mash.
- Residence Time In Fermentors.
- Fermentation Efficiency.

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Fermentation Plant

- **Main Sections:**
  - Yeast Propagation.
  - Fermentation.
  - Yeast Separation and Recycle.
  - Sludge Separation.
- **Auxiliary Sections:**
  - Handling & distribution of Inputs.
  - Cooling System.
  - Acid, Nutrients, Antifoam Supply.
  - Cleaning in Place System.

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Continuous Fermentation….

- More than 100 distilleries in Asia & India use continuous fermentation on cane molasses.
- Easier to operate with 2-4 fermentors , consistent quality & no need to propagate yeast daily.
- Higher efficiency of 89-90 % instead of 80-84 % in a batch process.
- Alcohol yield of 270-274 Lit of 99.5 % v/v Ethanol/ MT molasses with 48 % Fermentable Sugars (64-65 gallon/short ton).
- Alcohol concentration increases from 5-6 % in the 1st fermentor to 8-9.5 % in the last one.

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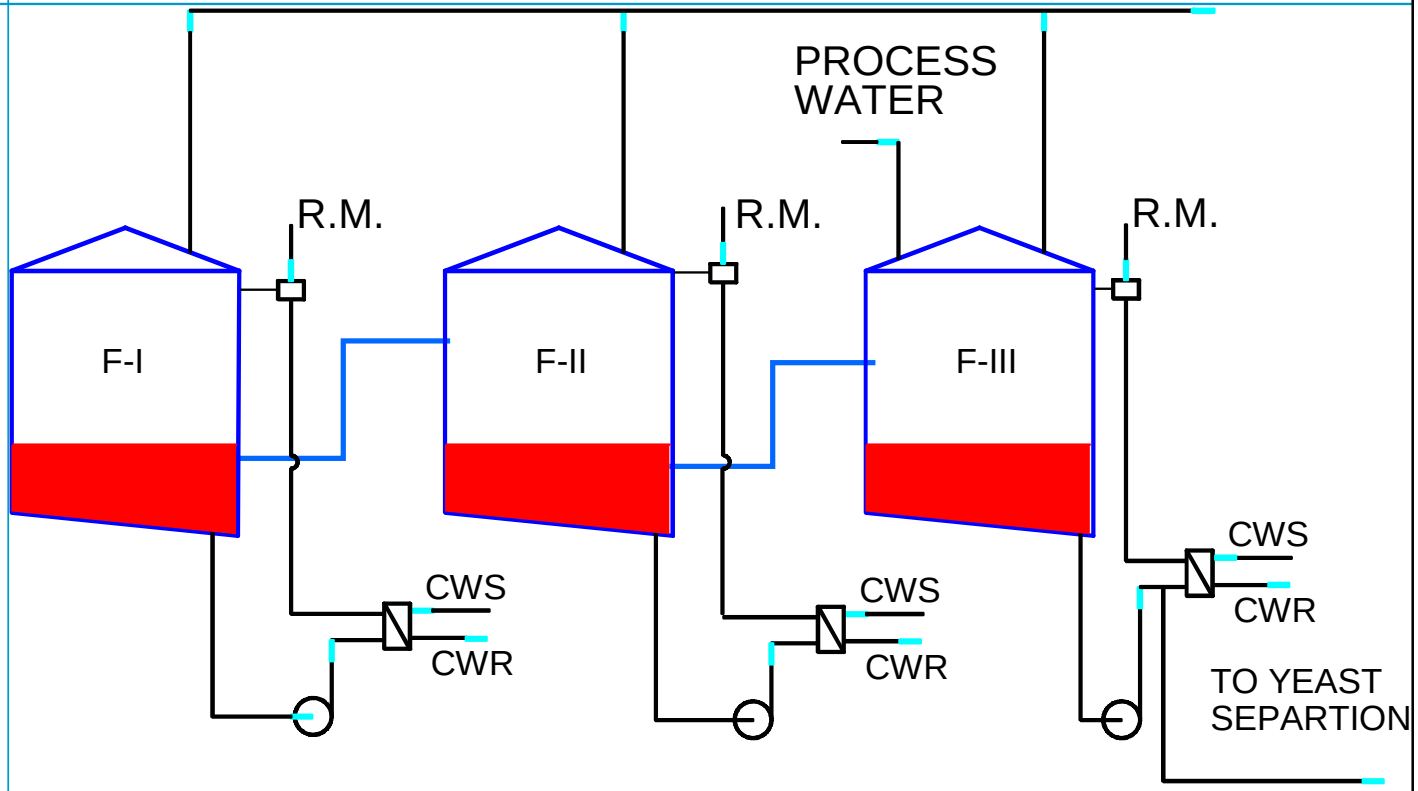
Continuous Fermentation



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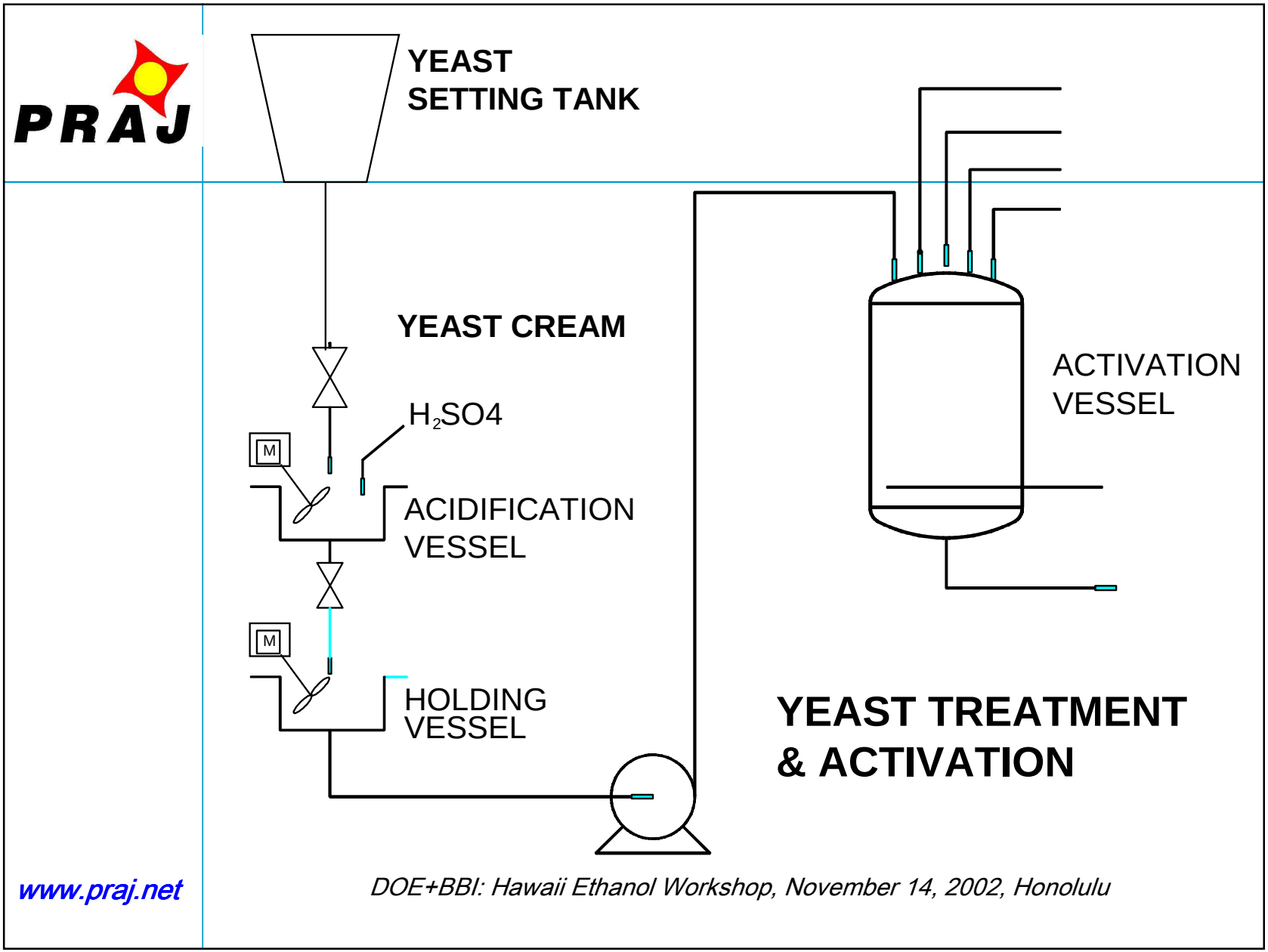
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YEAST
SETTING TANK
YEAST CREAM
H_2SO4
M
ACIDIFICATION
VESSEL
M
HOLDING
VESSEL
ACTIVATION
VESSEL
YEAST TREATMENT
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Ethanol Distillation

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What is Distillation ?

Separation of Liquid Mixture(s)
of Different Components
into a Number of Fractions of
Different Compositions
OR
into its Pure Components.

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Objective of Distillation

- Stripping of alcohol from Fermented Mash.
- Concentration of stripped alcohol to 95 - 96.5%v/v for industrial alcohol & further concentration to 99.5 - 99.8%v/v in dehydration plant for ethanol.
- Concentration of stripped Ethanol to 96 - 96.5 %v/v for Potable application. Separation of impurities become prime importance. Achieved by controlling-
  - Dilution & Extraction
  - Temperature.

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Parameters for Distillation.

- Number of distillation columns depend on required product composition.
- Selection of parameters like pressure & temperature
- Energy conservation by -
  Heat Recovery, Thermal Integration.
- Automation for consistency in quality.
- Plant Design to Take Care Fouling Nature of Mash.

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Distillation Scheme Selection

- Energy cost being a significant potion of operating cost, configuration is designed to minimize energy.
- Use of re-boilers to minimize volume of effluent.
- Using cascading pressure for integration of heat & saving in energy.
- Automation to get consistent quality product.

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Multi-pressure Vacuum Distillation

- Lower consumption of steam
- Multi-pressure vacuum configuration eliminates problems of scaling in mash column
- Consistently high quality of product
- Higher degree of instrumentation and automation

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Effluent Treatment

AN OVERVIEW OF

TECHNOLOGIES FOR TREATMENT OF VINASSE FROM CANE MOLASSDES DISTILLERIES

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Characteristics of Effluent

Effluent generated by molasses based distilleries has following characteristics:

Volume: 9 to 12 KL per KL of alcohol produced.

B.O.D.: 40,000 to 60,000 mg./ lit or ppm.

C.O.D.: 80,000 to 120,000 mg./lit or ppm.

Total solids: 7 to 12 % w/w.

Organic solids: 4 to 8 % w/w

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Objective For Effluent Treatment

- To ensure safe treatment of the organic part of the effluent
- To ensure safe and proper disposal of the treated effluent.

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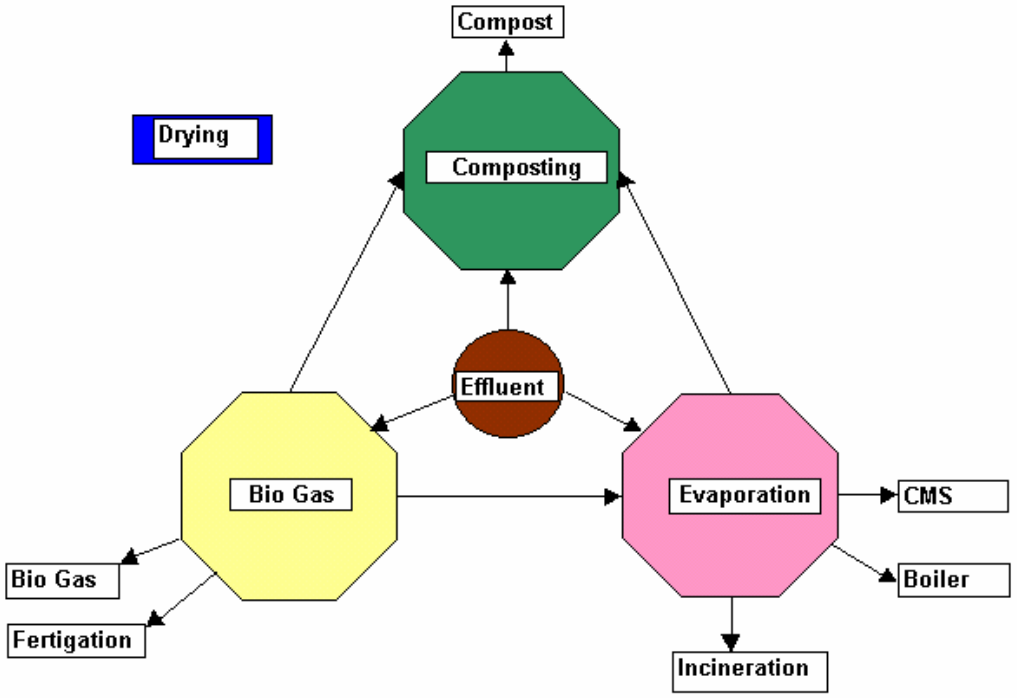
Options of Treatment of Vinasse



Methods of treatment

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Options / Schemes

- Anaerobic Bio-Methanation followed by aerobic, activated sludge treatment: almost 80 % of the energy requirement can be derived from vinasse.
- Aerobic, Biological Composting.
- Concentration and usage in Animal Feed (CMS).
- Concentration and Incineration, with and without Steam Generation.
- Ferti - Irrigation with bio-methanated or with partially evaporated vinasse.
- Disposal in water bodies like river,lake or sea.

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Recycle of Vinasse

- When using cane molasses or juice syrup, up to 50 % of vinasse can be recycled.
- Vinasse gets concentrated to 25-30 % solids.
- Careful process design required to avoid excessive build-up of bacterial contamination.
- Aspects like content of calcium & inorganic ash and content of bacteria & volatile acids need to be considered carefully.

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FLUBEX Evaporator Vinasse

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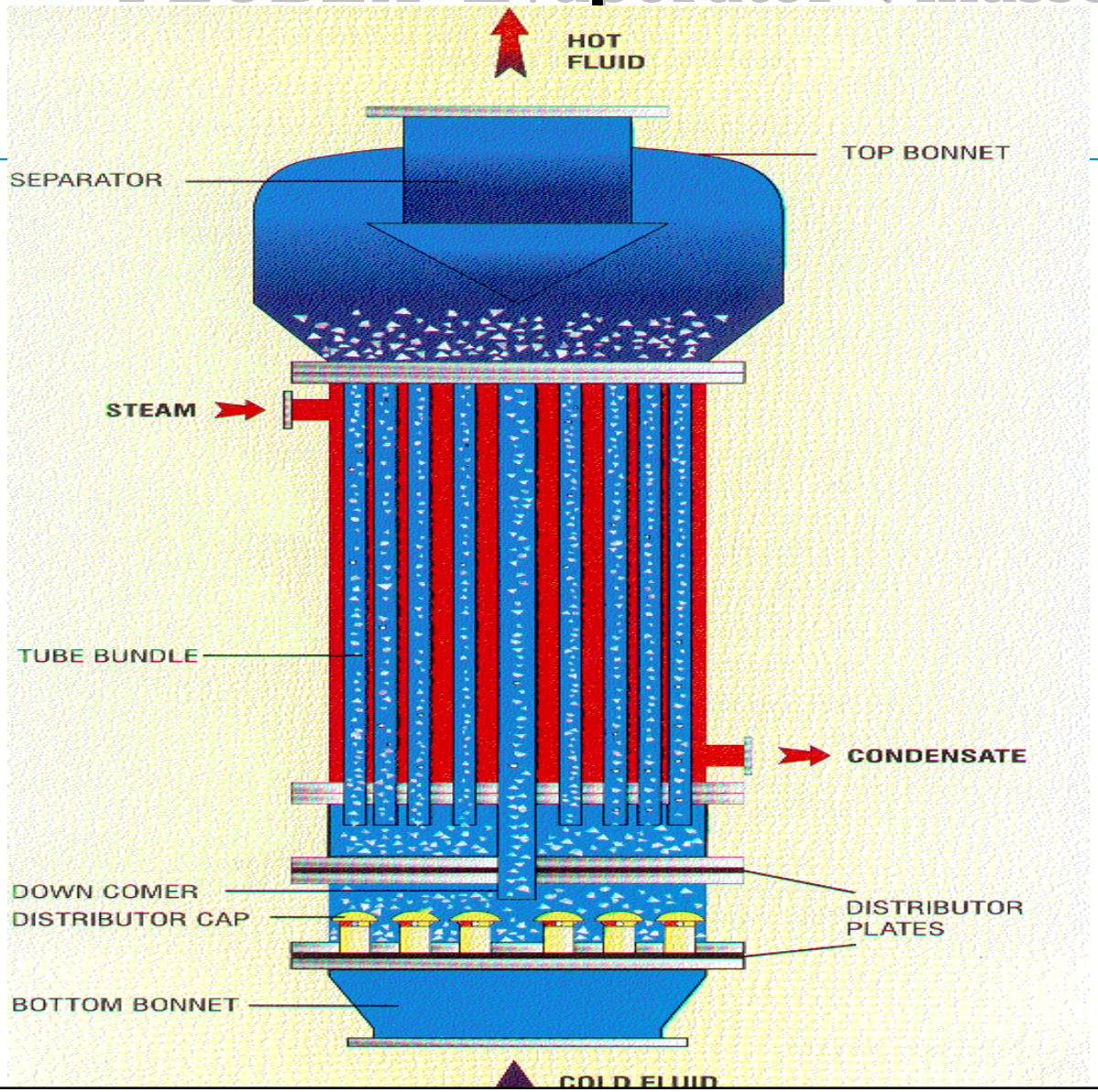

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Evaporation of Vinasse - '*FLUBEX*' . . . . .

- Deposition and scaling in falling film evaporators due to presence of calcium salts in vinasse is the major problem in evaporation of vinasse.
- Self-cleaning fluidized bed *FLUBEX* evaporators of PRAJ employs metal wire-bits which get fluidized in the exchanger and gently scour the tube-walls
- *FLUBEX* enables use of vinasse evaporator for a longer duration of 30-90 days without cleaning.

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Integration of *FLUBEX* Evaporator with Distillation

- Evaporation of Mash before distillation to produce high wine
- Vinasse gets concentrated to 50 % solids
- Use of vapors from Rectifier column under high pressure to heat the evaporator
- Steam consumption of < 3.7 kg/lit (31 lb/gallon) of alcohol for evaporation + distillation
- System eliminates use of Mash column and thus avoids related problems of scaling.

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FLUBEX Mash/Vinasse Evaporator

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Bio-methanation of Vinasse

Boiler

Flare

Blower

Bio-gas Holder

Vinasse from Distillery

Lime

DAP

Cooling water Out

Degassin Pond

Vinasse Settling Tk.

Buffer Tank

PHE

Bio-Digester

Cooling water In

Sludge Recycle

Sludge Drying Bed

Excess Sludge

Parallel Plate Clarifier

Sludge for Disposal

Treated effluent for Secondary Treatme

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Aerobic Open Wind-Row Bio-Composting of Vinasse

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Conclusions

- Appropriate technologies at affordable project investment are available for production of ethanol from cane molasses.
- Valuable energy and organic soil conditioner compost can be produced by treatment of vinasse.
- Variable cost of production will is between US Cents 75-95/gallon, depending upon factors like cost of molasses, technology used and the choice of vinasse treatment.

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Thanks Indeed !

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